The Accuracy of Single Tooth Mini Dental Implant Placement Using Computer Assisted Surgical Guide: A Randomized Clinical Trial Comparative Study

Voravan Vorasubin[1] Weerapan Aunmeungthong[1] Pathawee Khongkhunthian[1*]

Abstract

Background: This study aimed to assess the accuracy of mini dental implant placement using conventional surgical templates (CST) versus digital (computer assisted) surgical drill guides (SDG) for single tooth prosthesis.

Materials and methods: Sixteen participants recruited according to inclusion criteria. Twenty implants (16 participants) were randomly assigned to either the CST or SDG group. Mini dental implants were placed in the lower anterior and premolar area. The positioning of implants were analyzed and compared using Planmeca Romexis™.

Results: Statistical analysis using the Shapiro-Wilk test and independent sample T-test revealed significant differences between the two groups in 3 parameters out of 10 parameters: top horizontal deviation (CST; 1.43 ± 0.77 and SDG; 0.67 ± 0.3 mm), top global deviation (CST; 1.83 ± 0.85 and SDG; 0.82 ± 0.52 mm) and angular deviation (CST; 5.53 ± 3.14 and SDG; 1.36 ± 0.7 degrees) at $p < 0.05$.

Conclusion: CST and SDG are effective for placing single-tooth mini dental implants in limited-ridge spaces, especially in the anterior and premolar regions. Their versatility allows for adaptation to the specific circumstances of each case, ultimately enhancing clinical decision-making and patient outcomes.

Keywords: Surgical Drill Guide, Randomized Clinical Trial, Single-Tooth Dental Implant, Mini Dental Implants

Received Date: Jun 17, 2024
Revised Date: Nov 03, 2024
Accepted Date: Nov 11, 2024

[1] *Center of Excellence for Dental Implantology, Faculty of Dentistry, Chiang Mai University, Chiang Mai, 50200, Thailand.*
*(*corresponding author)*

Introduction

Dental implants have emerged as a reliable treatment option for edentulous patients, significantly enhancing their quality of life over recent decades (1,2).

According to Glossary of Dental Implantology (3), implants with diameters ranging from 3.5 to 5 mm are considered standard. Those with diameters less than 3.75 mm are often referred to as 'small', 'narrow', or 'mini' implants, although there remains some ambiguity in their classification (4). However, there's no strict rule governing the terminology of dental implants, as long as authors clearly describe the implant sizes.

Mini dental implants were originally used in orthodontic treatments as the anchorage for tooth movement. They were also used for edentulous treatments, such as single tooth restoration and implant-assisted prostheses with high survival rate (5,6). Additionally, they are categorized into two types: single-piece and two-piece. Single-piece implant have garnered interest for their suitability in narrow-ridged spaces and their reduction of complex surgical procedures. With stable occlusion and good primary stability, mini dental implants placed in areas with sufficient bone width and height can facilitate immediate loading of prostheses, showing a high survival rate of 98% at the 1-year follow-up (7).

The flapless surgical technique has gained interested for implant placement, offering greater patient comfort and satisfaction with reduced post-operative complications (8). Although, designing surgical guides and prefabricating prostheses may prolong the preparation time, flapless surgery minimizes the chair time. Notably, there's no significant difference in survival rates, complications, or marginal bone level changes between flapless and open-flap surgeries over a mean follow-up period of 21.62 months (9).

Three-dimensional implant positioning (bucco-lingual, mesio-distal, and apico-coronal) plays an important role in treatment success. Proper positioning allows implants to mechanically adapt to the host bone until secondary stability is achieved. Computer-guided surgical procedures are considered advantageous, especially for deficit alveolar ridges prone to resorption. (10,11).

The Fourth ITI Consensus Conference (2008) (12) defined the two computer technological applications in surgical implant dentistry i.e., computer-guided (static) surgery and computer-navigated (dynamic) surgery. Computer-guided surgery, utilizing static surgical templates, reproduces virtual implant positions from CT data, making it practical in dental practice where available working space is limited (13).

The adoption of computer-guided surgery has enhanced patient satisfaction and treatment acceptance compared to conventional implant placement surgery. It facilitates effective surgical time management and reduces complication rates by providing precise virtual implant positioning (14). Studies have focused on the accuracy of computer-guided surgery (13,15-22), with favorable outcomes reported, particularly for standard-size implants (15,23-25).

However, concerns remain regarding its application to mini dental implants, given the limited research in this area. Until recently, there was no research focus on the accuracy of placing single-tooth dental mini implants using a digital guide.

The objective of this randomized clinical trial is to evaluate the accuracy of single-tooth implant positioning in limited-ridge spaces, comparing conventional surgical guides with tooth-borne computer-assisted surgical guides.

The null hypothesis for this study is that there is no difference in the accuracy of implant positioning between the control group and the experimental group.

Materials and Methods

Study Approval and Registration

This randomized clinical trial study received approval from the Human Experimentation Committee, Faculty of Dentistry, Chiang Mai University no.34/2562. The study adhered to the ethical principles outlined in the World Medical Association (WMA) Declaration of Helsinki. Informed consent was obtained from all participants prior to their involvement in the study and the CONSORT 2010 checklist for reporting randomized trials was followed.

Sample Size Calculation

Sample size was calculated using mean and standard deviation (SD) of the angular deviation at the implant apex based on the results of the pilot study. The significance level (α) was set at 0.05 and power of test (1- β) was set at 80%. By the use of G*power program for sample size calculating resulted in n = 6 implants each group or n = 12 implants in total. In this study we use n = 10 implants each group and n = 20 in total. All participants should meet the criteria listed in Table 1.

Table 1. Inclusion and exclusion criteria of this study.

Inclusion criteria	Exclusion criteria
1. Patients aged 20-65 years	1. Requirement for bone or soft tissue grafting at the time of implantation
2. The site of the study has Bone height ≥11 mm and Bone width between 5-7 mm	2. Sufficient bone width for conventional size dental implant placement
3. No contraindication for minor oral surgery	3. Uncontrolled systemic disease, ASA Class III
4. No smoking or smoke less than 10 cigarettes per day during past 5 years	4. Presence of periodontal disease or periapical lesions
5. No psychosis or psychiatric disorders	5. Alcoholism or drug abuse
6. No uncontrolled bleeding disorders	6. Implant that need submersion due to stability issue
7. Never received radiotherapy around head and neck regions	7. Pregnancy or positive to pregnancy test
8. Good oral hygiene with ability to maintain adequate conditions	8. Physical or mental disorders which would effect the ability to maintain good oral hygiene
9. No history of intravenous injection of bisphosphonate	9. Patients whom not able to provide informed consent
10. Participants must agree to undergo treatment and follow-up for at least one year.	10. Conditions that would prevent completion of study participation

Examination and Randomization

Participants underwent CBCT imaging using DentiiScan© (NECTEC, Thailand). The DICOM files were retrieved for later analysis. Each participant was assigned a unique number. A blinded investigator (S.A.) used computer software to randomly assign participants to one of two groups: Group 1 (control) using Conventional Surgical Templates (CST) and Group 2 (experimental) using Surgical Drill Guides (SDG). These assignments were kept confidential from the surgeon until the implant position planning was complete. The mini dental implants planned during this step were available in two sizes: 2.7 mm in diameter with a length of 12 mm, and 3.0 mm in diameter with a length of 10 mm.

Mini Dental implants placement procedure

Both groups followed identical initial procedures, beginning with the administration of 4% articaine with epinephrine 1:100,000 for local anesthesia to ensure patient comfort during the surgery. Following the administration of anesthesia, either a full-thickness flap or a flapless technique was employed. A full-thickness flap was indicated in cases where bone concavity or complex morphology is identified on pre-operative cone beam computed tomography (CBCT). In the absence of these conditions, the flapless technique was utilized.

Group 1: Conventional Surgical Template (CST)

The conventional surgical template (Fig.1a) was fitted to ensure proper alignment. A 2.0 mm diameter pilot bur was used, followed by sequentially larger implant drilling burs to prepare the implant site. From the pilot bur to final bur all as performed through the template. The dental mini implant (NOVEM®, Novem Innovations Co., Ltd., Thailand) was placed using a free-hand technique.

Group 2: Surgical Drill Guide (SDG)

The protocol for Group 2 was similar to that of Group 1, with the primary difference being the use of a surgical drill guide (Fig. 1b) instead of the conventional surgical template. The drill guide was used to assist in the drilling and placement of the implant.

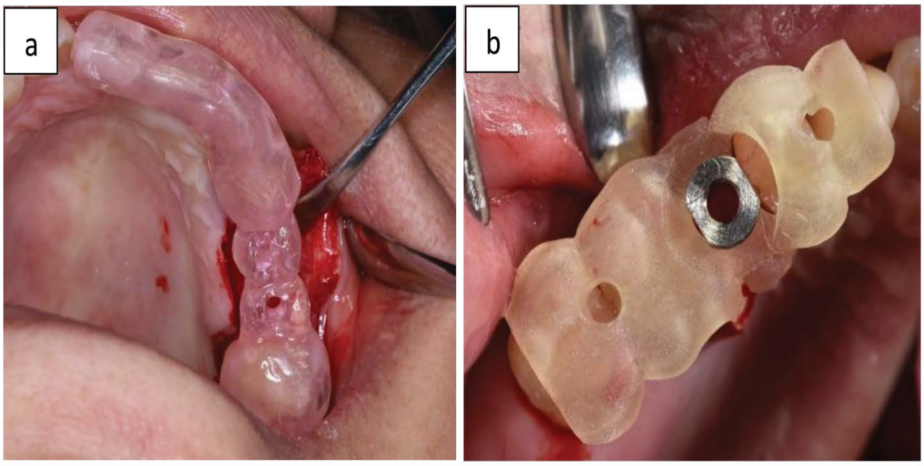

Fig.1 a: Conventional surgical template,
b: Surgical drill guide with metal collar.
Post-operative procedure.

A post-operative cone-beam computed tomography (CBCT) scan was conducted immediately after the surgery to analyze the implant position. Subsequently, the abutment, which is the same piece as the fixture, was prepared, and a temporary restoration was fabricated and fixed in place with temporary cement.

Discrepancy between planned and placed implant measurements

Discrepancies were measured from superimposed image between pre-operative CBCT and post-operative CBCT in millimeters for the nine parameters; Top horizontal deviation (TH), Top vertical deviation (TV), Top global deviation (TG), Coronal horizontal deviation (CH), Coronal vertical deviation (CV), Coronal global deviation (CG), Apical horizontal deviation (AH), Apical vertical deviation (AV), Apical global deviation (AG).

The deviation of the angle of the long axis between the planned and placed implants was also measured and recorded as Angular deviation (AD).

These parameters positions were shown in Fig. 2.

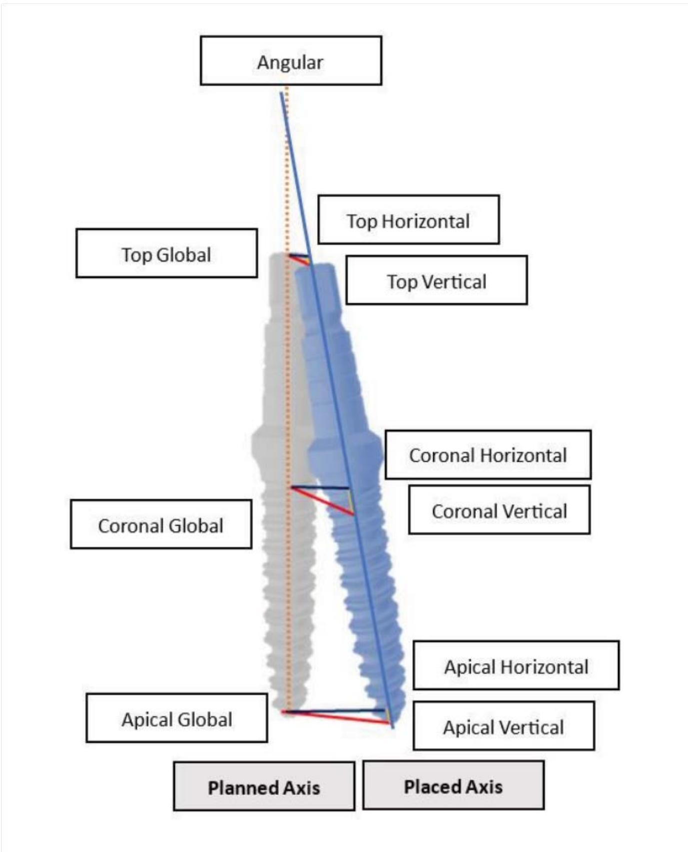

Fig.2 Evaluation parameters of planned and placed implant.

Data analysis and evaluation.

Alongside the completion of implant placement, the analysis of outcomes between the CST and SDG groups was performed by the same well-experienced surgeon and researcher of this study who hadn't been involved in randomization (P.V.). Self-calibration was performed using Cohen's kappa coefficient. Each patient's data was encoded by number ranging from No. 001 to No.020. The power of test was calculated by mean and SD of angular deviation resulted in 0.97 at 0.05 α probability level. Comparison between the planned and placed implant positions was determined in Planmeca Romexis™ software (Planmeca Co., Ltd., Helsinki, Finland) by means of pre and post-operative CBCT superimposition. All data parameters from both groups underwent thorough evaluation.

Statistical analysis

To assess the normal distribution of the data, the Shapiro-Wilk test was employed. Subsequently, statistical analysis was conducted using an independent sample T-test for comparison, utilizing SPSS 26 (IBM SPSS, USA). Statistical significance was defined as $p < 0.05$, indicating differences between groups.

Results

Participants were recruited at the Centre of Excellence for Dental Implantology, Faculty of Dentistry, Chiang Mai University. After evaluation of bone width and height using cone-beam computed tomography (CBCT), resulting in a final cohort of 16 individuals eligible for inclusion. These 16 participants underwent placement of 20 mini dental implants, with some individuals having the potential for placement in multiple areas.

The participants were randomly divided into two groups: the Conventional Surgical Template (CST) group and the Surgical Drill Guide (SDG) group. The CST group comprised 4 males and 4 females, while the SDG group consisted of 3 males and 4 females. The mean ages of the participants in each group were recorded (Table 2).

Table 2. Patient demographic data in each group.

		CST	SDG
Mean age		45.25 (29-66)	41.23 (24-61)
Gender			
	Male	4	3
	Female	4	4
Area			
	Anterior	5	3
	Premolar	5	7

The areas of interest for implant placement in this study were the lower anterior area and premolars area. The mini dental implant placement procedures were conducted over a period spanning from February 2020 to February 2023. All of the fabricated CSTs and SDGs met satisfactory stabilization and were fitted properly. There were no complications following the procedure and no implants were lost throughout the entire process. Then the evaluation process was executed as described in materials and methods (Fig.3)

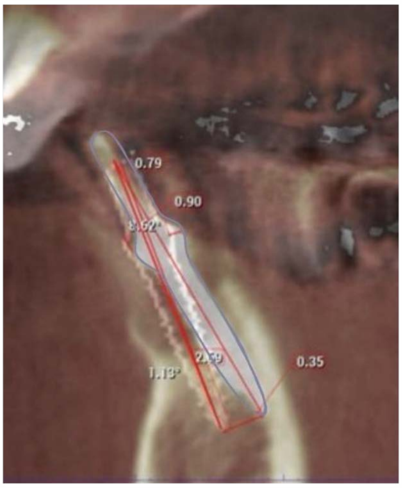

Fig.3 Evaluation of discrepancy between planned and placed implants using Planmeca Romexis™.

The results revealed that there were statistically significant differences of the discrepancy measurements ($p < 0.05$), between the CST and SDG groups, in 3 parameters including the top horizontal, top global and angular deviation as shown in Table 3.

Table 3. Discrepancy between planned and placed implants in two groups.

Parameters		Conventional surgical template (n = 10) Mean ± SD (mm)	Surgical drill guide (n = 10) Mean ± SD (mm)	p-value
Top	Horizontal	1.43 ± 0.77	0.67 ± 0.3	0.013*
	Vertical	0.93 ± 0.71	0.63 ± 0.59	0.319
	Global	1.83 ± 0.85	0.82 ± 0.52	0.005*
Coronal	Horizontal	1.09 ± 0.55	0.87 ± 0.41	0.326
	Vertical	0.99 ± 0.88	0.74 ± 0.56	0.463
	Global	1.57 ± 0.53	1.22 ± 0.48	0.142
Apical	Horizontal	1.37 ± 0.1	0.8 ± 0.4	0.12
	Vertical	1.29 ± 1.2	0.65 ± 0.57	0.15
	Global	1.75 ± 0.92	1.2 ± 0.46	0.12
Angular deviation		5.53 ± 3.14 degrees	1.36 ± 0.7 degrees	0.002*

Discussion

The present study aimed to compare the accuracy of single tooth implant positioning in narrow ridge spaces between conventional surgical guides and computer-assisted surgical guides. Through a randomized clinical trial design, we sought to contribute valuable insights into the efficacy of computer-assisted techniques in mini dental implant placement, thereby informing clinical practice and future research endeavors.

Our study identified top horizontal deviation, top global deviation and angular deviation as the most significant discrepancies, differing from previous findings of Ngamprasertkit et. al. highlighting only global deviation (26). The observed discrepancies may arise from the procedural nuances associated with mini dental implants. Unlike conventional methods that rely extensively on drilling burs to facilitate significant angle adjustments, the mini implant procedure entails a more conservative use of such tools, potentially limiting the extent of angle alterations. Additionally, the small size of the uppermost portion-specifically, the top of the abutment in the single-piece design of mini dental implants-presents challenges for visualization and precise placement during the surgical procedure. Further research on this topic may necessitate exploring additional possibilities.

The observed discrepancies may arise from the presence of adjacent teeth, as well as the quadrant and specific location of the implant site. Notably, the number of missing teeth did not appear to influence the outcomes (27). In our study, the limited types of teeth examined made it challenging to determine whether tooth location affects accuracy. Similarly, there is currently no established relationship among the flap or flapless surgery techniques regarding their accuracy. Continued investigation into both issues is warranted.

In terms of prosthesis procedure, the angulation of the implant showed a significant effect on linear displacement of impressions when its larger than 25 degrees (28). However, there is no known direct connection with the survival rate or functionality of dental implant.

The successful integration of mini dental implants hinges significantly upon the surgeon's manual dexterity and clinical acumen. This stands in contrast to the guided implant insertion technique (26), which afford greater predictability through meticulous preoperative planning. This disparity underscores the critical role of surgical technique in influencing procedural outcomes.

Clinically, despite the observed discrepancies, the use of CST provided no different clinical outcomes compared to SDG. Immediately following the procedure, there were no complications or negative feedback from participants in either group. This suggests the capability of both techniques, followed by the potential for broader adoption of computer-assisted techniques in mini dental implant placement. While computer-guided surgery has traditionally been associated with standard-sized implants, our study suggests its feasibility and efficacy in the context of mini dental implants. This expansion of the scope of computer-assisted implantology offers clinicians greater versatility in treatment planning and execution. Although the differences in parameters between the two groups were not substantial, the use of SDG may be superior to CST in terms of ease of use during surgical implant placement. Novice surgeons can more readily adhere to the steps for implant placement, thereby facilitating the efficient execution of the procedure within an appropriate chair time.

Meanwhile, several limitations should be acknowledged. Firstly, the relatively small sample size in this study may limit the generalizability of the findings. Future research with larger cohorts is warranted to validate the outcomes and explore innovative strategies for participant recruitment and refine implant placement protocols to enhance accuracy and predictability.

Additionally, our study focused solely on implant positioning accuracy and did not assess other crucial clinical parameters such as peri-implant soft tissue health, patient satisfaction, or long-term implant survival rates. Future investigations should incorporate comprehensive outcome measures to provide a more holistic evaluation of treatment success and patient outcomes.

Overall, our study sheds light on the nuances of surgical template fabrication and implant placement procedures, highlighting the importance of precise techniques and the potential impact on treatment outcomes.

Conclusion

In conclusion, CST and SDG demonstrate effective applicability for the placement of single-tooth mini dental implants in limited-ridge spaces, particularly within the anterior and premolar regions. This versatility offers a broader array of techniques that can be adapted to the specific circumstances of each mini dental implantation case, enhancing clinical decision-making and improving patient outcomes.

Acknowledgements

The authors express special thanks to Chiang Mai University officers who provided resources and accommodated in the research, Dr.Thanapat Sastraruji for statistical analysis consultant. This research was supported and funded by Chiang Mai University, Chiang Mai, Thailand.

References

1. Buser D SL, De Bruyn H. Modern implant dentistry based on osseointegration: 50 years of progress, current trends and open questions. Periodontology 2000. 2016;73(1):7-21.

2. Block MS. Dental implants: the last 100 years. J Oral Maxillofac Surg. 2018;76(1):11-26.

3. Khalid Almas FJ, Steph Smith. Glossary of Dental Implantology. Wiley-Blackwell; 2018.

4. Al-Johany SS, Al Amri MD, Alsaeed S, Alalola B. Dental implant length and diameter: a proposed classification scheme. J Prosthodont. 2017;26(3):252-60.

5. Aunmeungtong W, Kumchai T, Strietzel FP, Reichart PA, Khongkhunthian P. Comparative clinical study of conventional dental implants and mini dental implants for mandibular overdentures: a randomized clinical trial. Clin Implant Dent Relat Res. 2017;19(2):328-40.

6. Threeburuth W, Aunmeungtong W, Khongkhunthian P. Comparison of immediate-load mini dental implants and conventional-size dental implants to retain mandibular Kennedy class I removable partial dentures: a randomized clinical trial. Clin Implant Dent Relat Res. 2018; 20(5):785-92.

7. Zembic A, Johannesen LH, Schou S, Malo P, Reichert T, Farella M, et al. Immediately restored one-piece single-tooth implants with reduced diameter: one-year results of a multi-center study. Clin Oral Implants Res. 2012;23(1): 49-54.

8. Brodala N. Flapless Surgery and Its Effect on Dental Implant Outcomes. Int J Oral Maxillofac Implants. 2009:24(Suppl):118-25.

9. Lemos CAA, Verri FR, Cruz RS, Gomes JML, Dos Santos DM, Goiato MC, et al. Comparison between flapless and open-flap implant placement: a systematic review and meta-analysis. Int J Oral Maxillofac Surg. 2020;49(9):1220-31.

10. Javed F, Ahmed HB, Crespi R, Romanos GE. Role of primary stability for successful osseointegration of dental implants: Factors of influence and evaluation. Interv Med Appl Sci. 2013;5(4):162-7.

11. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: Anatomic and surgical considerations. Int J Oral Maxillofac Implants. 2004;19 (Suppl): 43-61.

12. Proceedings of the 4th International Team for Implantology (ITI) Consensus Conference, August 2008, Stuttgart, Germany. Int J Oral Maxillofac Implants. 2009;24 Suppl:7-278.

13. Younes F, Cosyn J, De Bruyckere T, Cleymaet R, Bouckaert E, Eghbali A. A randomized controlled study on the accuracy of free-handed, pilot-drill guided and fully guided implant surgery in partially edentulous patients. J Clin Periodontol. 2018;45(6):721-32.

14. Al Yafi F, Camenisch B, Al-Sabbagh M. Is digital guided implant surgery accurate and reliable?. Dent Clin North Am. 2019;63(3):381-97.

15. Bover-Ramos F, Vina-Almunia J, Cervera-Ballester J, Penarrocha-Diago M, Garcia-Mira B. Accuracy of implant placement with computer-guided surgery: a systematic review and meta-analysis comparing cadaver, clinical, and in vitro studies. Int J Oral Maxillofac Implants. 2018; 33(1):101-15.

16. Chai J, Liu X, Schweyen R, Setz J, Pan S, Liu J, et al. Accuracy of implant surgical guides fabricated using computer numerical control milling for edentulous jaws: a pilot clinical trial. BMC Oral Health. 2020;20(1):288. doi: 10.1186/s12903-020-01283-4.

17. Colombo M, Mangano C, Mijiritsky E, Krebs M, Hauschild U, Fortin T. Clinical applications and effectiveness of guided implant surgery: a critical review based on randomized controlled trials. BMC Oral Health. 2017;17(1):150. doi: 10.1186/s12903-017-0441-y.

18. Cristache CM, Gurbanescu S. Accuracy evaluation of a stereolithographic surgical template for dental implant insertion using 3d superimposition protocol. Int J Dent. 2017;2017:4292081. doi: 10.1155/2017/4292081.

19. Derksen W, Wismeijer D, Flugge T, Hassan B, Tahmaseb A. The accuracy of computer-guided implant surgery with tooth-supported, digitally designed drill guides based on CBCT and intraoral scanning. a prospective cohort study. Clin Oral Implants Res. 2019;30(10):1005-15.

20. Fang Y, An X, Jeong SM, Choi BH. Accuracy of computer-guided implant placement in anterior regions. J Prosthet Dent. 2019;121(5): 836-42.

21. El Kholy K, Lazarin R, Janner SFM, Faerber K, Buser R, Buser D. Influence of surgical guide support and implant site location on accuracy of static Computer-Assisted Implant Surgery. Clin Oral Implants Res. 2019;30(11):1067-75.

22. Miller RJ, Bier J. Surgical navigation in oral implantology. Implant Dent. 2006;15(1):41-7.

23. Hultin M, Svensson KG, Trulsson M. Clinical advantages of computer-guided implant placement: a systematic review. Clin Oral Implants Res. 2012;23(Suppl 6):124-35.

24. Gargallo-Albiol J, Barootchi S, Salomo-Coll O, Wang HL. Advantages and disadvantages of implant navigation surgery. a systematic review. Ann Anat. 2019;225:1-10. doi: 10.1016/j.aanat.2019.04.005.

25. Unsal GS TI, Lakhia S. Advantages and limitations of implant surgery with CAD/CAM surgical guides: a literature review. J Clin Exp Dent. 2020;12(4):409-17.

26. Ngamprasertkit C, Aunmeungthong W, Khongkhunthian P. The implant position accuracy between using only surgical drill guide and surgical drill guide with implant guide in fully digital workflow: a randomized clinical trial. Oral Maxillofac Surg. 2022;26(2):229-37.

27. Tang T, Huang Z, Liao L, Gu X, Zhang J, Zhang X. Factors that Influence Direction Deviation in Freehand Implant Placement. J Prosthodont. 2019;28(5):511-8.

28. Mir Mohammad Rezaei S, Geramipanah F, Kamali H, Sadighpour L, Payaminia L. Effect of Arch Size and Implant Angulations on the Accuracy of Implant Impressions. Eur J Prosthodont Restor Dent. 2021;29(4):218-22.

Corresponding author:
Prof.Dr.med.dent. Pathawee Khongkhunthian
Center of Excellence for Dental Implantology,
Faculty of Dentistry, Chiang Mai University,
Chiang Mai, Suthep 50200, A. Muang, Thailand
50200
Tel: (665) 394 4484
E-mail: pathaweek@gmail.com